General Geology of Simpang Pulai Area with Emphasis on Kaolin Resources

by

Muhammad Akmal bin Mohd Ihwan

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Petroleum Geosciences Programme

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In partial fulfillment of the requirement for the

BACHELOR OF TECHNOLOGY (HONS)

PETROLEUM GEOSCIENCES

Approved by,

………………………………..

(A.P. Dr. Chow Weng Sum)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the acknowledgement and references, and that the original work contained herein has not been undertaken or done by unspecified sources or persons.

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(MUHAMMAD AKMAL BIN MOHD IHWAN)

Abstract

This project focuses on the geology of the Simpang Pulai area with emphasis on the kaolin deposits in the area. Different rocks sample from the outcrops were collected during the field work and thin section analysis were conducted. Also a detailed geological mapping of the Simpang Pulai area was produced on the scale of 1:50000. A few kaolin samples were taken from the outcrops for detailed physical and chemical analysis. The chemical, mineralogical and textural characteristics of the kaolin deposits in Simpang Pulai area were studied using X-ray fluorescence, X-ray diffraction and thin section analysis. In order to investigate the quality of the kaolin and its suitable uses in the industry, particle size distribution, brightness, whiteness and yellowness test, and LOI were conducted. Based on the field data and laboratory results, the Kaolin in Simpang Pulai area is a product of primary (in-situ) and hydrothermal weathering of minerals in granite especially feldspar. The occurrences of quartz-feldspar vein and nearby hotspring are proofs of hydrothermal fluid influx system of the area. The fact that the kaolin occurrence was found within the granite and at the slope of the hill instead of a flat ground further proves the primary formation of the kaolin. The dominant mineral of Kaolin is kaolinite, with subordinate quartz and feldspar. The silicon dioxide content in Kaolin ranges from 75.1% to 76.1%. The Alumina content is around 16% and they have very low iron content and alkali content, average 0.03% and 0.01% respectively, showing its low impurities. Particle size distribution results show almost 100% of particle size are under 30μm for developed kaolin deposits, while 85% for underdeveloped kaolin deposits. The LOI percentages of all samples of Kaolin are around 6% which indicate its low firing shrinkage. The brightness of Kaolin in Simpang Pulai is around 84% which is considered excellent, with high whiteness and low yellowness percentage supporting the result. It is estimated that the undeveloped kaolin deposits, U, have reserves about 5000m^3. The kaolin is suitable for several industrial applications such as ceramic industry, filler industry, and fertilizer industry.

Acknowledgement

First of all, I praise God, the almighty for providing me this opportunity and granting me the strength and capability to complete the Final Year Project successfully. A million appreciations to all parties for the commitment, support and advise given in assisting the author to achieve the objectives of the project and thus complete the requirement to finish the undergraduate study at Universiti Teknologi Petronas.

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1.1 Background of Study

Kaolin formation is basically due to the weathering and hydrous alteration of feldspar. It can be processed and can be used as the main ingredient in the production of paint and as the filler for paper. The formation of Kaolin begins when long periods of physical weathering break down the rocks into finer grain sizes. This allows an accelerated rate of chemical weathering ore mineral decomposition to occur. This occurrence is either primary (in-situ) or secondary (been transported and re-deposited). The Kaolin is considered of high quality if it has finer particle size and high brightness percentage.

Simpang Pulai is town in the Kinta Valley which is located between Sungai Raia and Chandan Desa. Geologically the area consists of metasedimentary and granitic rocks. The area is underlain by marble and schist, and a granite batholith in the east. Schist of Paleozoic (Devonian-Permian) age is the oldest rock. It only occupies a narrow zone between the younger Kinta Limestone comprises recrystallized marble and the Slim granite to the east.

1.2 Problem Statements

The problem statements of this project are as follow:

- There is no geological map of Simpang Pulai area on a scale of 1:50000.
- The reserves of the Kaolin deposits in Simpang Pulai area are unknown.
- The Kaolin is presently used for making ceramics and research has to be carried out to check its suitability for other uses.

1.3 Objectives

The objectives of this project are as follow:

- To conduct a detailed study on the general geology of Simpang Pulai area on a scale of 1:50000 from outcrop mapping.
- To study the quality of the kaolin and its suitable uses in the industry.
- To understand the genesis of the kaolin deposits.

1.4 Scope of The Project

This final year project called “Geology of Simpang Pulai Area with Emphasis on Kaolin Resources” is divided into two main parts. The first part will focus on the geology of the Simpang Pulai area. Basically, different rocks sample from the outcrops will be collected during the field work and then thin section analysis will be conducted. Also a detailed geological mapping of the Simpang Pulai area will be produced on the scale of 1:50000. Next, the second part will focus on the kaolin in the same area. A few kaolin samples will be taken from the outcrops. Then the samples are used for detailed physical and chemical analysis. On top of that, the quality of the kaolin and its suitable uses in the industry as well as its genesis will also be investigated and analyzed.

Chapter 2: Literature Review and Theory

2.1 Simpang Pulai

In the year 1870's geological studies were started in Perak. These studies mainly focused on tin mining. The geologic setting has contributed to the historical background and development of Kinta Valley which contain one of the major tin fields of Malaysia. The geology of Kinta Valley areas is well documented by Ingham & Bradford (1960). The area is basically underlain by an extensive limestone bedrock formation which is called Kinta Limestone. This is an extensive and thick limestone, which its age spans from Lower Palaeozoic (Ordovician) to Upper Palaeozoic (Permian).

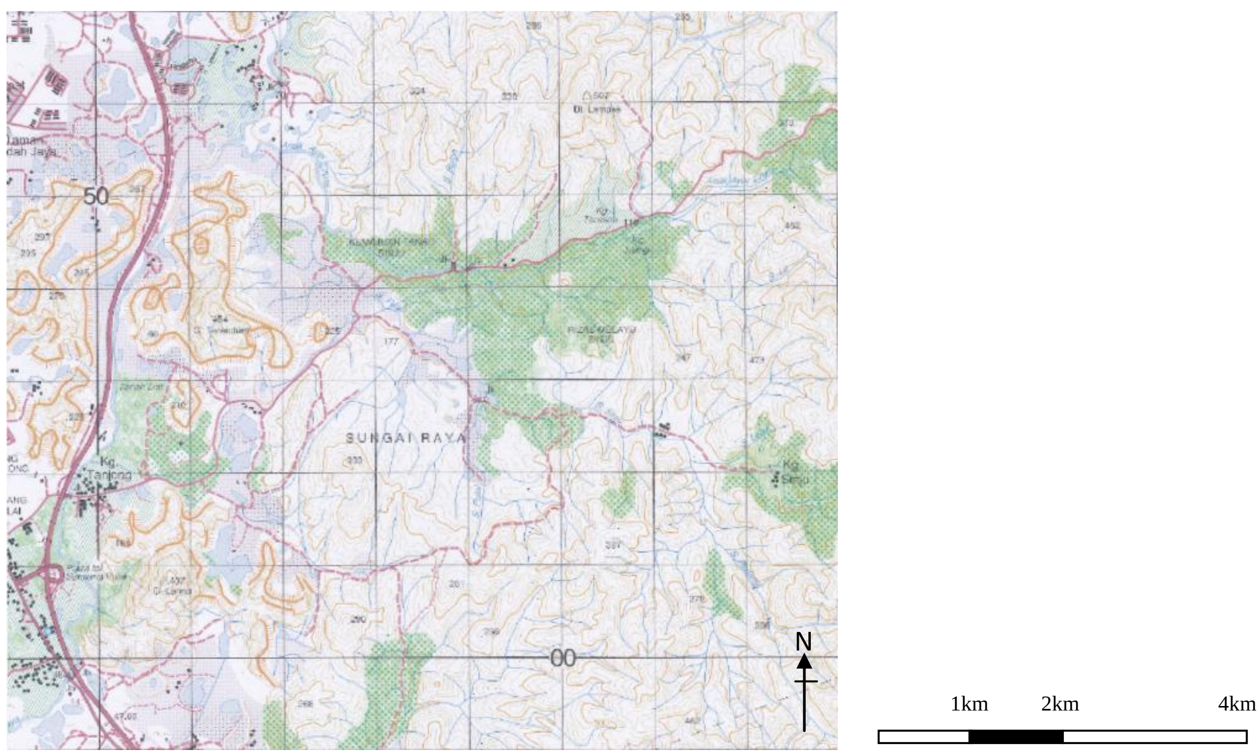

Figure 1: Map of Simpang Pulai

The Simpang Pulai area encompasses metasedimentary and granitic rocks. Metasediment rocks are of sedimentary origin that has undergone metamorphism due to high temperature and high pressure. The detailed geology of the area was documented by Teh (1969), Tan (1972), Ariffin Suhaidi (1993) and Mohd Azamie and Azman

(2003). The studies basically explain that the Simpang Pulai area and its area nearby are underlain by marble, schist and granite. The oldest rock is found to be Schist of Palaeozoic. This is only found in a narrow zone between the younger Kinta Limestone and the Slim granite. It is found that there are quartz veins deposited within the granite by late-phase fluids, upwelling through fracture planes and joint. Therefore intense koalinisation of feldspar and chloritisation of biotie were found (Tan, 1972).

The exposure of extensive occurrence of white kaolinitic clay was due to the cutting of hill slopes of Simpang Pulai-Pos Slim road. Major occurrence of kaolinised overburden are found that was cut through by the road (Kamar Shah Ariffin, Haryati Abdul Rahan, Hashim Husin & Kahirul Anwar Abdul Hadi, 2008).

2.2 Kaolin

As documented by Heinrich Ries (1927), "the term kaolin was originally used to refer to white residual clays of a white or nearly white burning character, but in recent years it has been stretched tp cover certain white sedimentary clays." The formation of Kaolin begins when long periods of physical weathering break down the rocks into finer grain sizes. This allows an accelerated rate of chemical weathering ore mineral decomposition to occur. This occurrence is either primary (in-situ) or secondary (been transported and re-deposited). The Kaolin is considered of high quality if it has finer particle size and high brightness percentage. The physical and chemical properties of kaolin are dependent on the environment of deposition, geological origin and method of processing. Presence of impurities such as iron oxide and titanium bearing materials would lower the quality of kaolin and its industry values.

Kaolin is grouped under Kaolinite, $Al_2Si_2O_5(OH)_4$. This is a clay mineral that contains atom of silicon, aluminium, oxygen, ferrous, and ferric iron. Kaolin belongs to silicate family with non-expandable 1:1 layer. The main constituent of Kaolin is the hydroxyl group. In theory, the composition of kaolinite in terms of oxides is SiO_2 46.56%; Al_2O_3 39.50%; H_2O 13.96%.

Kaolin or Kaolinitic clay is an industrial mineral which is generally used as fillers for paper or raw materials in paints, plastics, rubber, catalyst, ceramic, pharmaceutical formation, ink etc. Kaolin is mainly used in the paper industry as a pigment both as filler and coating. Grain size and brightness are two main properties that affect the commercial value of kaolin. Other properties that also affect the value are such as colour, abrasiveness, ease of dispersion, viscosity, pH, soft texture as well as lamellar particle shape.

Chapter 3: Methodology / Project Work

The methodology that was be used throughout this study encompasses field mapping, sample collection, sample analysis, thin section analysis and laboratory analysis.

3.1 Project Activities Workflow

The author has planned a project workflow in order to achieve the objectives stated.

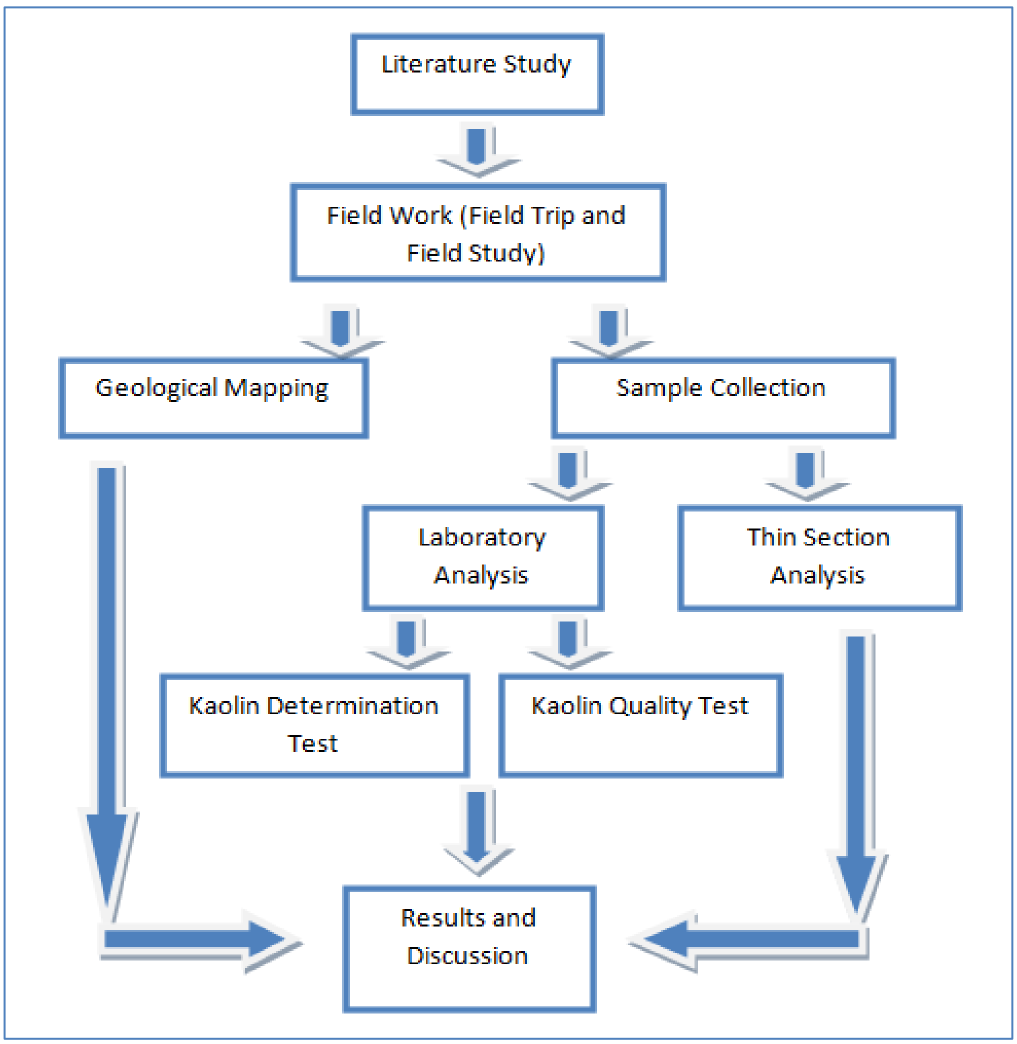

Figure 2: Workflow of the project

3.2 <u>Field Work and Geological Mapping</u>

Several field work were conducted to do the geological mapping and to collect samples. The Simpang Pulai geological map would be produced on the scale of 1:50000 and the mapping will be conducted by using a road traversing method as well as the global positioning system (GPS) method.

3.3 <u>Sample Collection and Petrography Analysis</u>

During the field work, rock samples were collected from the outcrops for petrography analysis thus obtaining petrographic descriptions such as mineral composition, structure, color, texture, grain size, weathering classification, and geological classification. Furthermore, kaolin samples will be collected from various outcrops as well as from the new undeveloped kaolin deposits.

3.4 <u>Laboratory Analysis</u>

The objective of laboratory analysis was to study the samples' physical and chemical properties and characteristics. Thin section analysis was conducted for limestone and granite samples while XRD, and XRF analysis were conducted for kaolin determination test. Meanwhile, for kaolin sample quality test, the particle size distribution test, the brightness test and LOI test were implemented.

3.4.1 <u>This Section Analysis</u>

In thin section analysis, a 0.03 mm thick slice of the rock sample that was used to view the microscopic image of the rock by using a microscope. Therefore its characteristic can be well defined.

3.4.2 X-Ray Fluorescence (XRF)

XRF is an analytical method to perform elemental analysis or to determine the chemical composition of a material. A Brucker XRF machine was used to conduct this analysis. About 5g of powder form of kaolin sample is used in this process. When an atom is excited by an external energy source, it emits X-ray photons of a characteristic wavelength or energy. The detector is then used to count the number of photons from each energy emitted from the kaolin sample. This therefore leads to identification of chemical element or oxides contained in the sample.

Figure 3: Bruker XRF Machine

3.4.3 X-Ray Diffraction (XRD)

XRD technique produces analytical information about the chemical composition and crystallographic structure of natural and manufactured materials, thus it can define the kaolin and its mineral composition. A powder form of kaolin sample about 5 gram was used for this test. The theory is that the x-ray released by the XRD will intercept with one another due to atomic planes of a crystal. Then we can identify the arrangement and crystalline orientation in order to investigate the atomic arrangement and properties of the material.

3.4.4 Particle Size Distribution

The kaolin quality can be determined by particle size distribution analysis. Theoretically the finer the grain size of the kaolin deposit the better the quality. This particle size distribution test was done by using an x-ray sedigraph machine. A dried and powdered sample of Kaolin was used for this process. The sample was mixed with sodium hexaametaphosphate dissolved in 100ml of distilled water. It was then sieved to 350 mircon and was put into the x-ray sedigraph machine to measure the particle size distribution.

3.4.5 Brightness Test

Minolta Spectrophotometer CM-500d was used in brightness test which measures the light of four different wavelength reflected over the sample. The brightness, whiteness and the yellowness of the kaolin samples can be obtained from this test. Basically the higher the percentage of brightness and whiteness as well as the lower the percentage of yellowness leads to a higher quality of the kaolin. A powdered and dry sample of kaolin is required for this analysis and it was first sieved with 350 micron. The sample is then putted into a cylinder of brass ring and some pressure is applied to the sample for about 2 minutes. Then a Minolta spectrometer was used to read the percentage of the reflectance, hence the percentage of the brightness, whiteness and yellowness of the sample.

Figure 4: Minolta Spectrophotometer CM-500d

3.4.6 LOI Test

LOI refers to Loss on Ignition test which is an analysis to determine the firing shrinkage of a material. It basically measures the mass loss of a combustion residue when it is heated to high temperature. In this test a dried and powdered sample of kaolin is required. After measuring its initial mass, the sample is heated up to 900°C. Then the mass loss due to the heating with oxygen is measured after cooling the content at room temperature. This test is one of the methods of industrial characterization of the kaolin for ceramic industry and other uses.

3.4 Gantt Chart and Key Milestones

Table 1: Gannt Chart and Key Milestones for the Project

Activities	Week														
	FYP 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Preliminary Research															
Proposal Defense															
Extended Proposal															
Interim Report															
Literature Study															
Field Work															
Thin Section															
XRF															
Brightness Test															
LOI Test															
Particle Size Test															
XRD															
Progress Report								☆							
Pre-Sedex											☆				
Dissertation Report													☆		
Technical Report													☆		
Viva														☆	
Dissertation Hard bound															

Chapter 4: Results and Discussion

4.1 <u>General Geology of Simpang Pulai Area</u>

The Simpang Pulai area is basically underlain by granite, limestone and schist. Most part of Simpang Pulai is covered by granite, as the granite is found to be most widely distributed rock along the Simpang Pulai – Pos Slim road. The limestone is distributed in limestone hills known as Gunung Lanno and Gunung Terendum. Schist is identified at the boundary between the younger Kinta Limestone and the Slim granite.

Furthermore, kaolin is located at the northwestern part of Simpang Pulai, specifically in a part of Bukit Lampas. The Kaolin deposits are made possible by the quartz veins deposited within the granite by late-phase fluids, upwelling through fracture planes and joint. Therefore intense koalinisation of feldspar and chloritisation of biotite were found.

The environment of deposition of Simpang Pulai area is probably marine environment. The karst formations which are limestone hills may indicate deep marine environment. Schist is the oldest rock which is of Paleozoic (Devonian – Permian) age, while Kinta Limestone is of Palaezoic (Carboniferous) age and Slim Granite is of Mesozoic (Triassic) age.

The study area of Simpang Pulai which is about 49km^2 has been studied and a map has been produced on the scale of 1:50000. Kaolin deposits are found in the Northeast direction of the study area. In the western side of the area, alluvium is found and sand tailing is located as a result of mining in the central part of the area which is between limestone and granite.

4.1.1 <u>Road Traversing</u>

This method of road traversing is used in this study in which the author traveled along the Simpang Pulai – Pos Slim road in order to produce a geological map of Simpang Pulai area. The distance of the traverse is about 7.0km. A digital GPS and a compass were used to record the coordinate and dip and strike readings of each outcrops found along the road. The path of the road traversing done is recorded and shown in the diagram below.

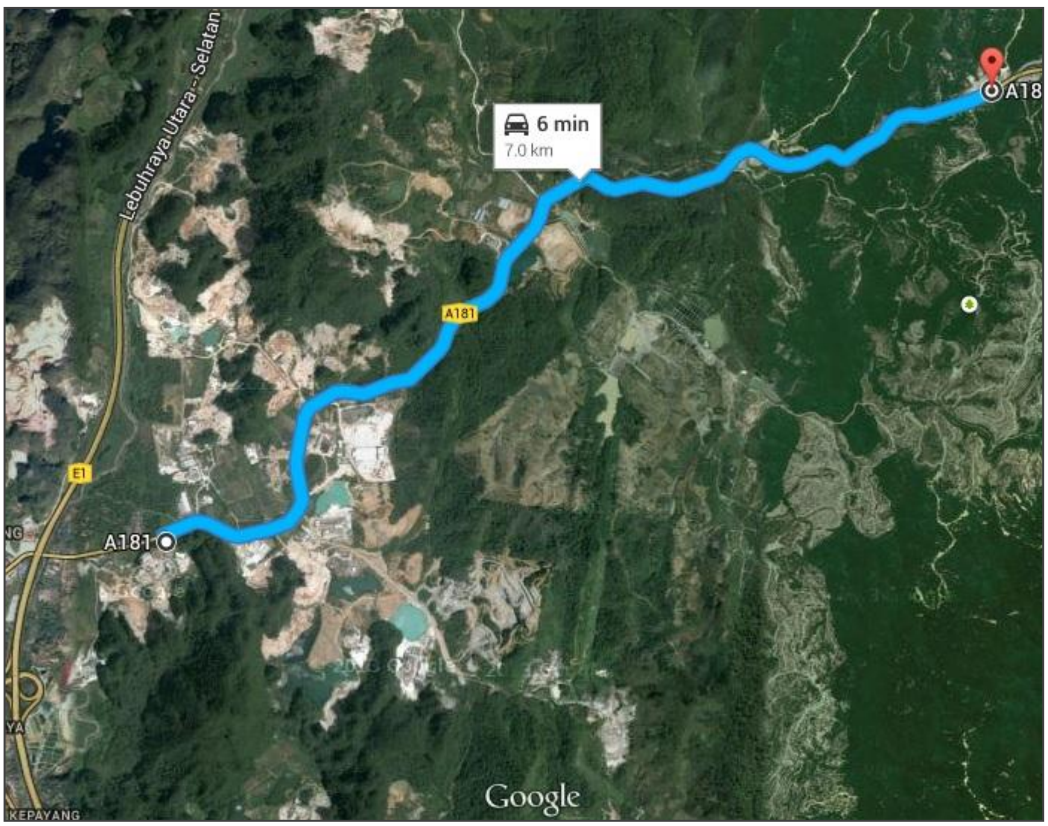

Figure 5: The path of road traversing done in Simpang Pulai

4.1.2 <u>Kaolin</u>

Based on geological field work that was done, the Kaolin occurrence was found by the Simpang Pulai – Pos Slim road to Cameron Highland. The extensive occurrence of the white kaolinitic clay was observed at the cutting of hill slopes of the road between km 12 and km 13. The major overburden is at least 2 cut slopes along the road which cuts through part of Bukit Lampas near Simpang Pulai.

The Kaolin deposits which cover a part of Bukit Lampas is easily accessible and observed. The location of the kaolin deposits is found at 04°33”N to 101°11.5”E and the distance is about 200m long. The border of the kaolin deposits is the road on the western side and by Sungai Anak Ayer China on the southern side. The figure below shows the outcrops observed to be an extensive formation of kaolinised material on a cut slopes in Bukit Lampas.

Figure 6: Kaolin mine in Simpang Pulai

Figure 7: Undeveloped kaolin deposit

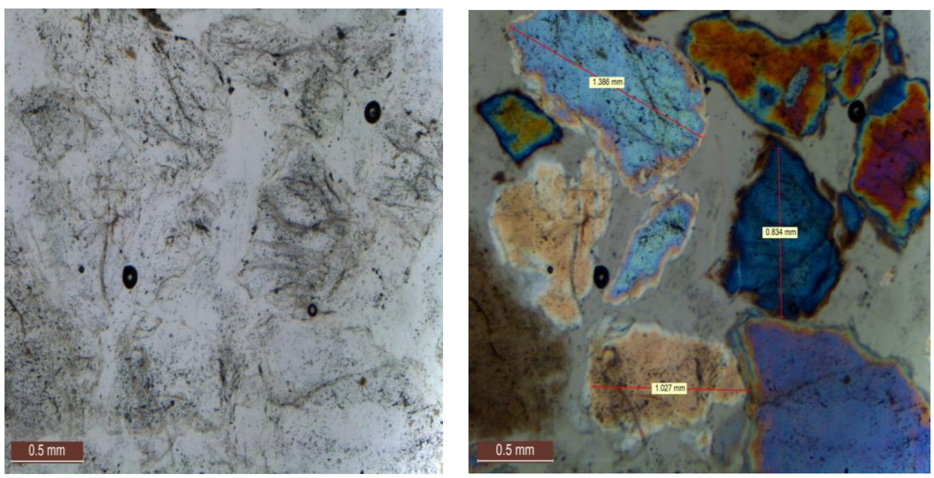

Figure 8: Kaolin thin section under plane polarize (left) and cross polarize (right) microscope

Based on the thin section of kaolin, the size of the quartz mineral is around 1 micron. The quartz observed has lack of cleavage and twinning but it has significant low birefringence as it changes of color when it is rotated under cross polarized microscope. The feldspar is shown to have zero birefringence and it is colorless in plane polarized microscope. The matrix is Kaolinite mineral with very fine grain which is the main mineral in the rock.

4.1.3 <u>Granite</u>

Granite was found in most of the places along the road, therefore the area is mainly underlain by the granite. Based on a study by Ariffin Suhaidi (1993), the area is predominantly underlain by the Slim granite. This is a part of the Main Range granite batholiths. It encompasses of coarse-grained prophyritic biotite granite, medium to coarse granite plus Late Triassic leucomicrogranite.

Figure 9: Granite Outcrop

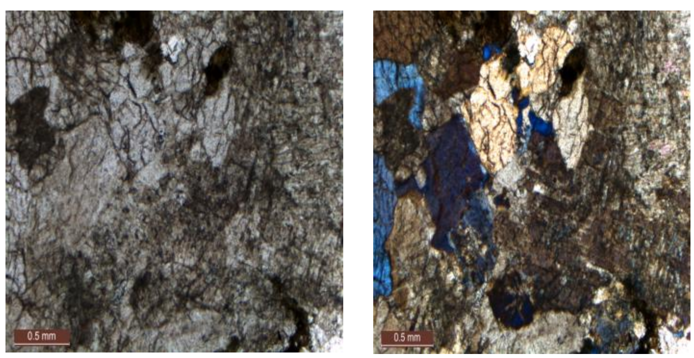

Figure 10: Granite thin section under plane polarize (left) and cross polarize (right) microscope

The thin section analysis shows that the granite is of medium to coarse grained. The granite consists of mainly quartz, plagioclase feldspar and biotite. The plagioclase feldspar shown in the thin section has birefringence but low relief. It also shows some form of twinning which differs from quartz. Meanwhile the quartz has low birefringence of the first order. The plagioclase feldspar could be the main mineral in this sample.

4.1.4 Limestone

Based on Scrivenor (1931), the limestone in the Kinta valley is carboniferous and the Quartzite and shale series (equivalent to the “schists” or greater part of them) are Triassic. This area consists of limestones and marble. The quality of the marble will increase as the $CHCO_3$ percentage increases. A study of limestone in Simpang Pulai area was conducted which includes visiting a limestone quarry company. A small cave like structure by the road was also observed. This structure has some underground water running and there are some usual cave structures like the stalactite and the stalagmite.

Figure 11: Limestone Outcrop

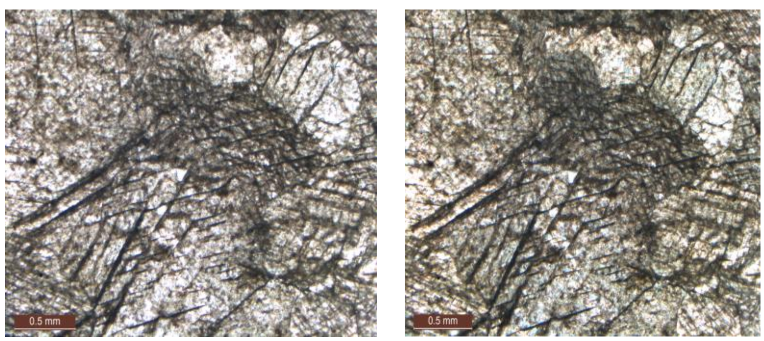

Figure 12: Limestone thin section under plane polarize (left) and cross polarize (right) microscope

Based on the thin section above, the main mineral is found to be calcite as shown in the white color mineral. We can see many lines indicating cleavages in calcite mineral. The limestone has undergone compressional forces. This would mean that the limestone has metamorphosed into marble.

4.2 <u>Geological Map</u>

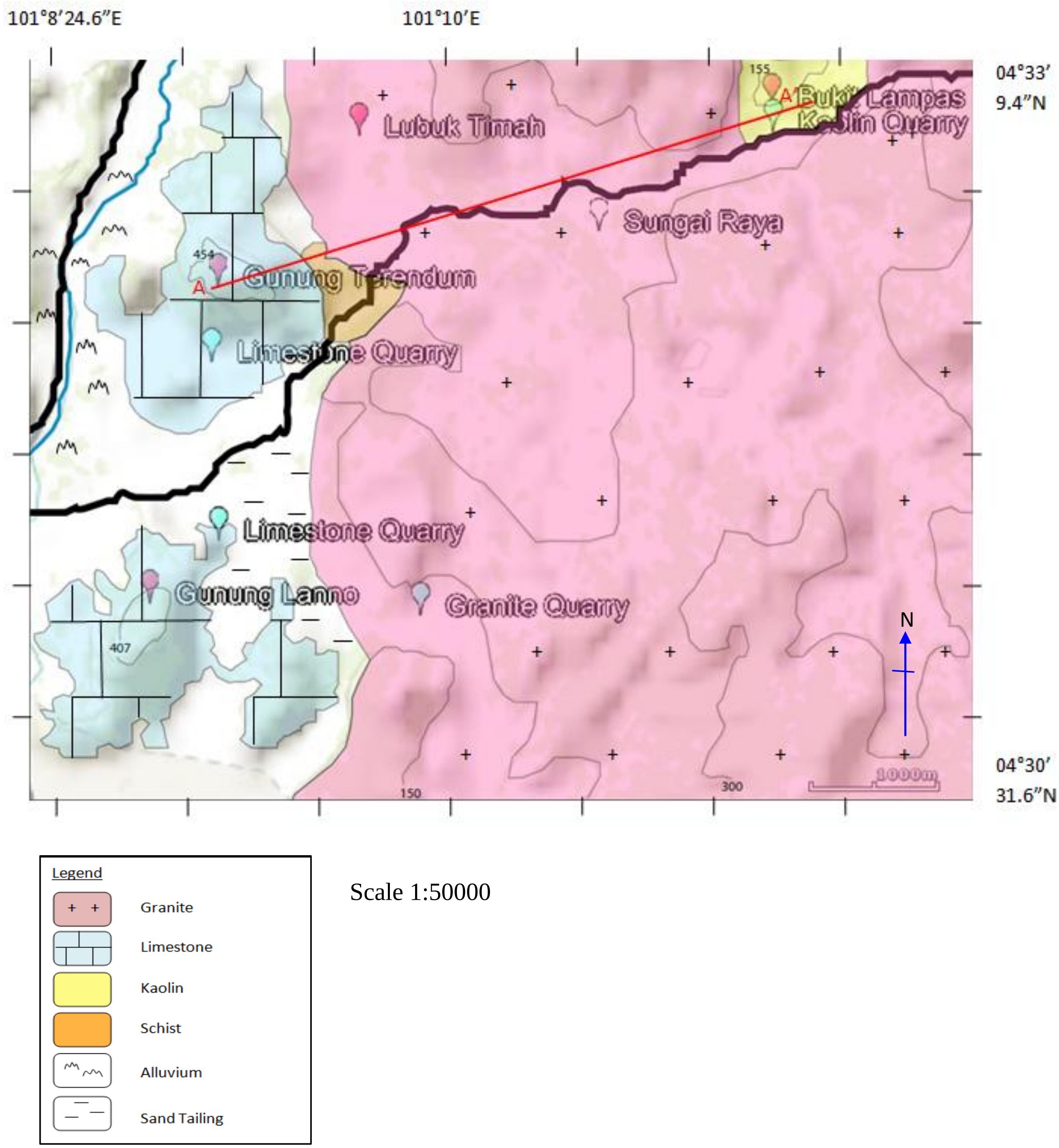

Figure 13: Geological map of Simpang Pulai area

Alluvium was present in the residential or village area along the river while sand tailing was observed in the former mining pit locations in between limestone hill, Gunung Lanno and granite batholiths.

A cross section showing lithology was produced along transect A to A’ in the geological map. This cross section displays the elevation and lithology along the transect line which is 5.05km long. Based from the map, we can see the limestone hill, schist in between limestone and granite, grainite batholiths and kaolin deposit from west to east of Simpang Pulai.

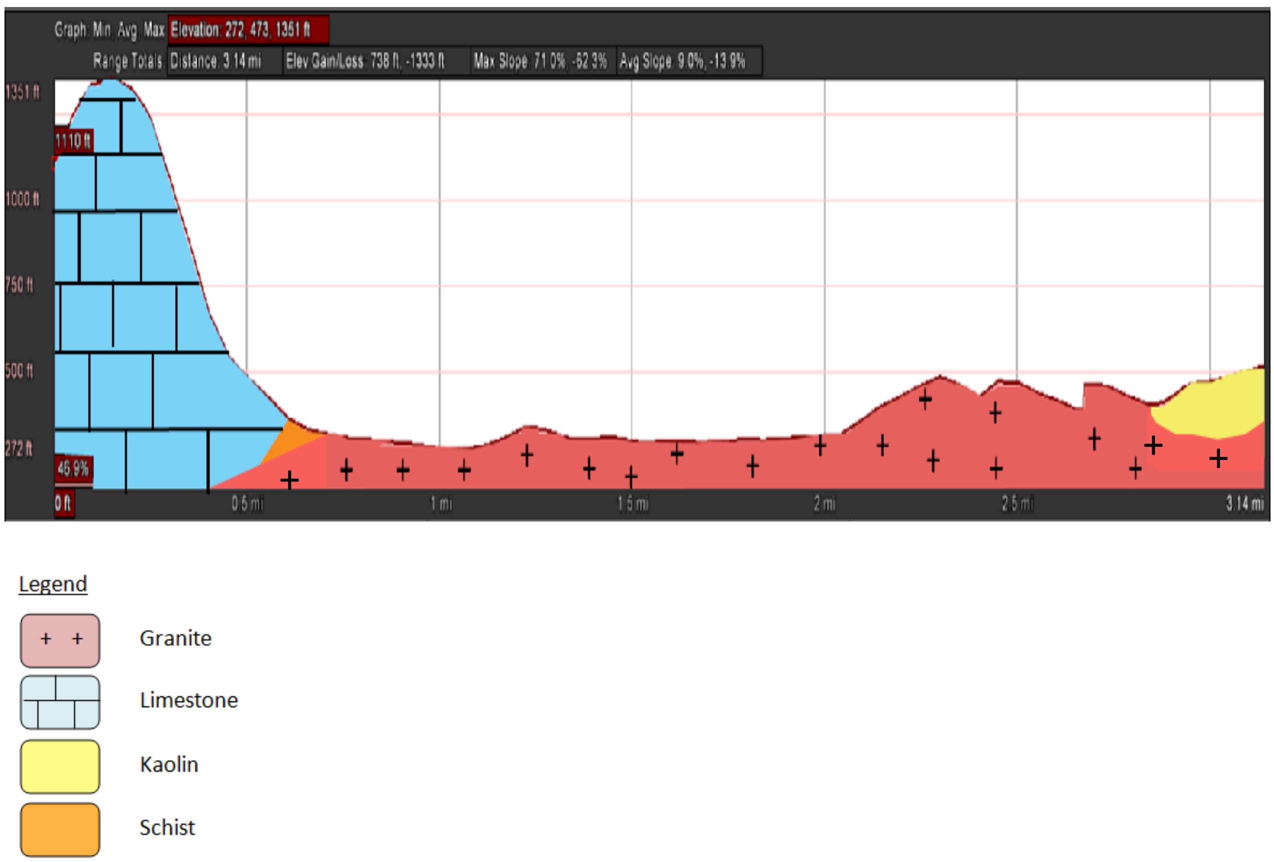

Figure 14: Cross section map of A-A’ with lithologies

4.3 Genesis of Kaolin Deposit

The formation of Kaolin begins when long periods of physical weathering break down the rocks into finer grain sizes. This allows an accelerated rate of chemical weathering ore mineral decomposition to occur. This occurrence is either primary (in-situ) or secondary (been transported and re-deposited). The Kaolin is considered of high quality if it has finer particle size and high brightness percentage. In this area, Kaolin is found at the cutting of hill slopes of the road of Simpang Pulai – Pos Slim.

The kaolin deposit in this area is found to be both in situ and hydrothermal weathering of minerals from granite. The predominant clay mineral of the Kaolin in Simpang Pulai area is Kaolinite. Based on the studies by Kamar Shah Ariffin et al (2008), the evidences of hydrothermal weathering are occurrences of quartz-feldspar veins, silification and illite alteration. Also, quartz, feldspar and illite occur subordinately and halloysite occurs locally. The physical and chemical properties of kaolin in this area were found to be of good quality.

The formation of kaolin in Simpang Pulai was initiated when feldspar minerals of the granite batholiths and nearby rocks were undergone weathering by weathering as stated by Kamar Shah Ariffin et al (2008). The feldspar is weathered due to its interaction with acidic hydrothermal fluid in high temperature environment which occurred in the area. The process is known as hydrothermal alteration or hypogene process of the granite that leads to kaolinisation. This results in alteration of feldspar to kaolinite. Further leaching of dissolved materials such as K^+ and Na^+ ions removed them from kaolin. The kaolin in Simpang Pulai area is formed in-situ as whitish clay bordering quartz veins in granite batholiths as well as formed as interlocked masses within interstices grayish to clear quartz. Moreover, the presence of quartz feldspar vein found and nearby hot water spring which is Lubuk Timah are the proofs of hydrothermal fluid influx system of the Simpang Pulai area (Kamar Shah Ariffin et al, 2008). The fact that the kaolin occurrence was found within the granite and at the slope of the hill instead of a flat ground further proves the primary formation of the kaolin.

4.4 <u>Kaolin Sampling</u>

In this study, several kaolin samples have been collected from three different locations in order to conduct several laboratory analyses which include Kaolin determination tests and kaolin quality tests. The first and second samples of kaolin, T-1 and T-2, are taken from the kaolin deposits in Tinex Sibelco mining area. The third sample of kaolin, sample U is taken from undeveloped kaolin deposits about 500m from the mining area. Laboratory analyses which are X-ray Diffraction, X-ray Fluorescence thin section analysis, whiteness, brightness and yellowness test, particle size, and LOI test were conducted to study the chemical, physical, mineralogical, and quality of the Kaolin in the Simpang Pulai area.

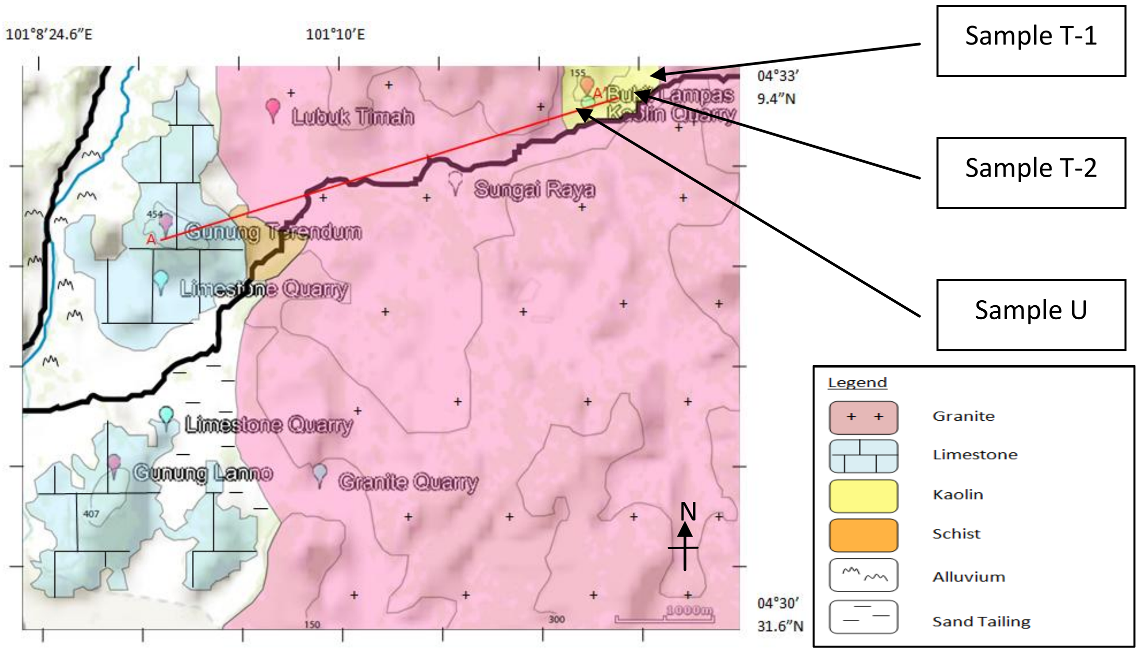

Figure 15: Kaolin Sampling in Simpang Pulai area

4.5 X-Ray Fluorescence

Chemical analysis using X-ray fluorescence was done for all three samples in order to study the chemical composition of the kaolin in Simpang Pulai area.

Table 2: XRF results showing chemical composition of kaolin samples

Sample	Chemical Composition (%)									
	SiO_2	AL_2O_3	Fe_2O_3	TiO_2	Na_2O	K_2O	CaO	MgO	MnO	P_2O_5
T-1	76.1	16.9	0.02	0.04	0.01	0.03	0.28	0.09	< 0.01	0.01
T-2	76.2	16.8	0.03	0.03	0.01	0.03	0.26	0.11	< 0.01	0.01
U	75.1	16.6	0.04	0.02	0.01	0.38	1.06	0.1	0.01	0.02

Table 1 above shows the chemical composition data from XRF of all three samples. The silica content in Kaolin ranges from 75.1% to 76.1%. This high silica content confirms that the rock is kaolin as kaolin is a silicate rock. Also it indicates the abundant of quartz as well as feldspar. The Alumina content is around 16% and they have very low iron content which is 0.03%. Their alkali content is also very low which is 0.01%. These low alumina, iron and alkali contents show that the kaolin is of good quality and has low impurities. Thus it indicates that the kaolin can meet the requirements and suits the industrial use. Crude clay from kaolin mine seems to have lower iron oxide. The content of Magnesium Oxide may be due to the presence of biotite in kaolin. Another detailed XRF was done and the result shows similar figures except that there is significant content of Zirconium, Zr. Hence the significant contents of Zr, P_2O_5, and TiO_2 are proof of the presence of zircon, apatite and ilmenite.

4.6 <u>X-Ray Diffraction</u>

X-ray diffraction method is basically done in order to detect the minerals associated with the kaolin samples, therefore determining the kaolin lithology. In this analysis, all three samples were used. The result shows all samples indicate a positive result where the samples are containing the kaolinite mineral and quartz mineral.

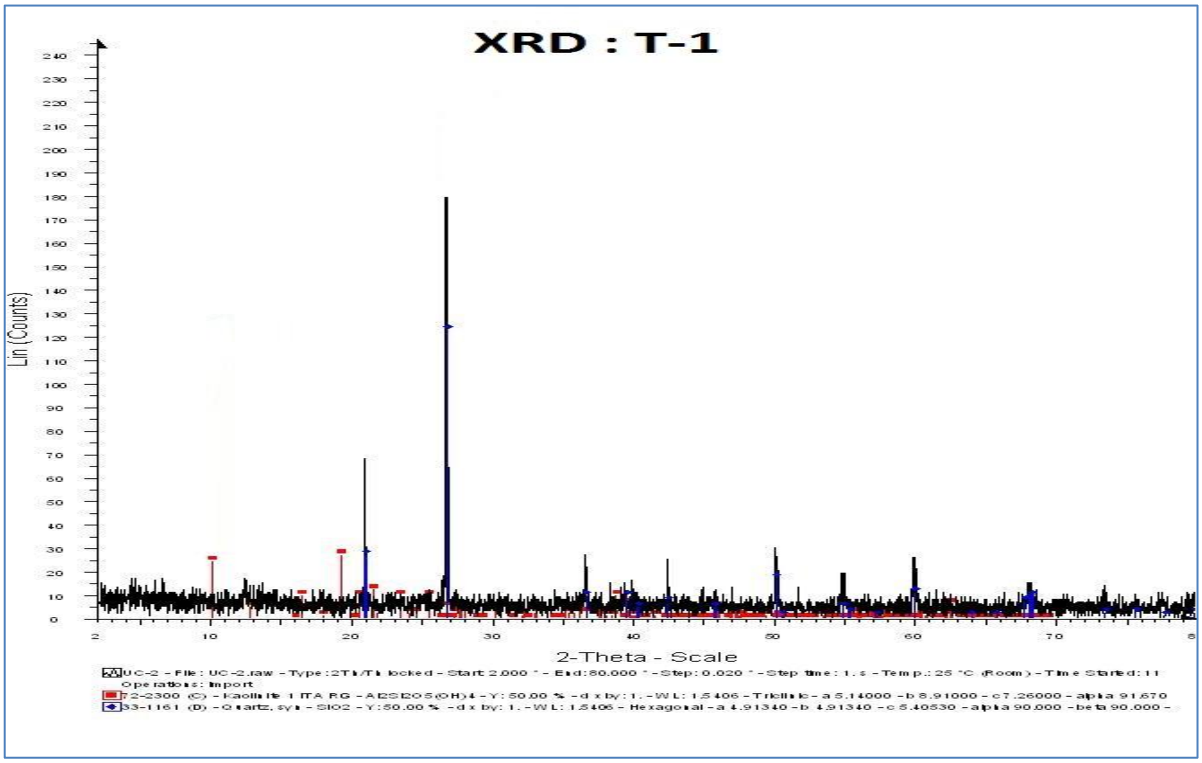

Figure 16: XRD result for sample T-1

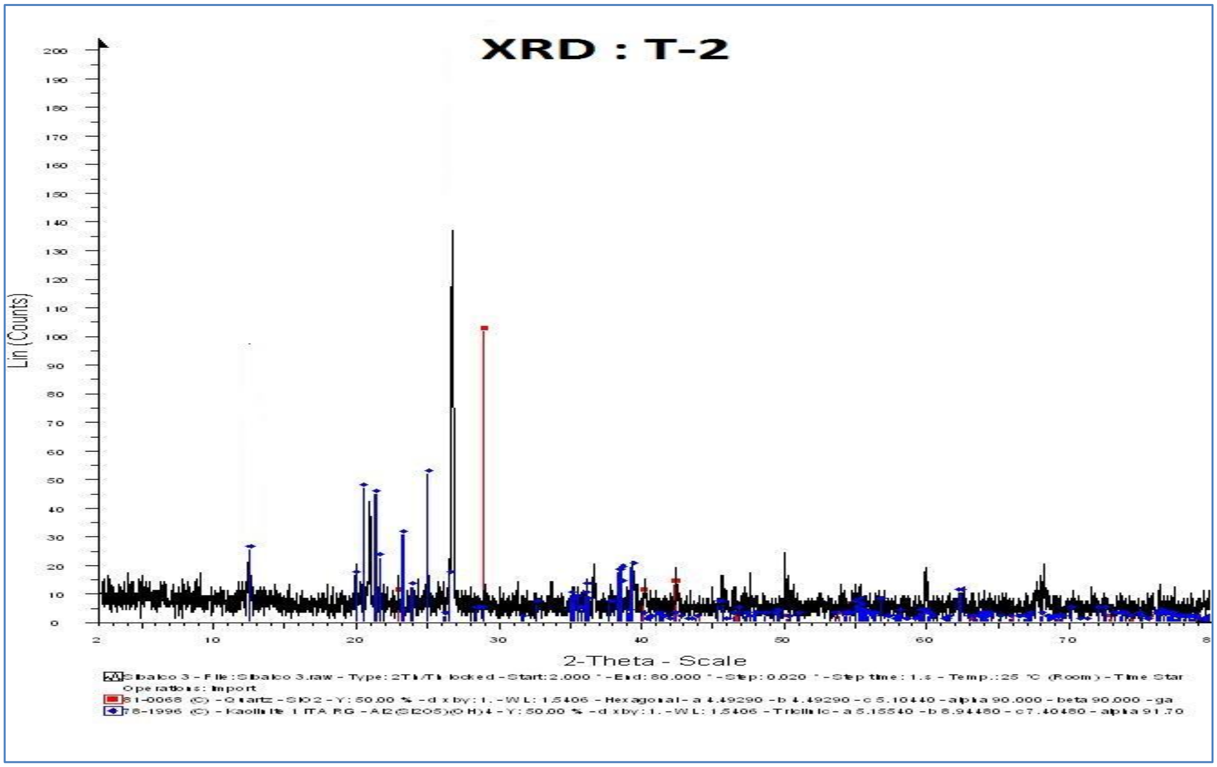

Figure 17: XRD results for sample T-2

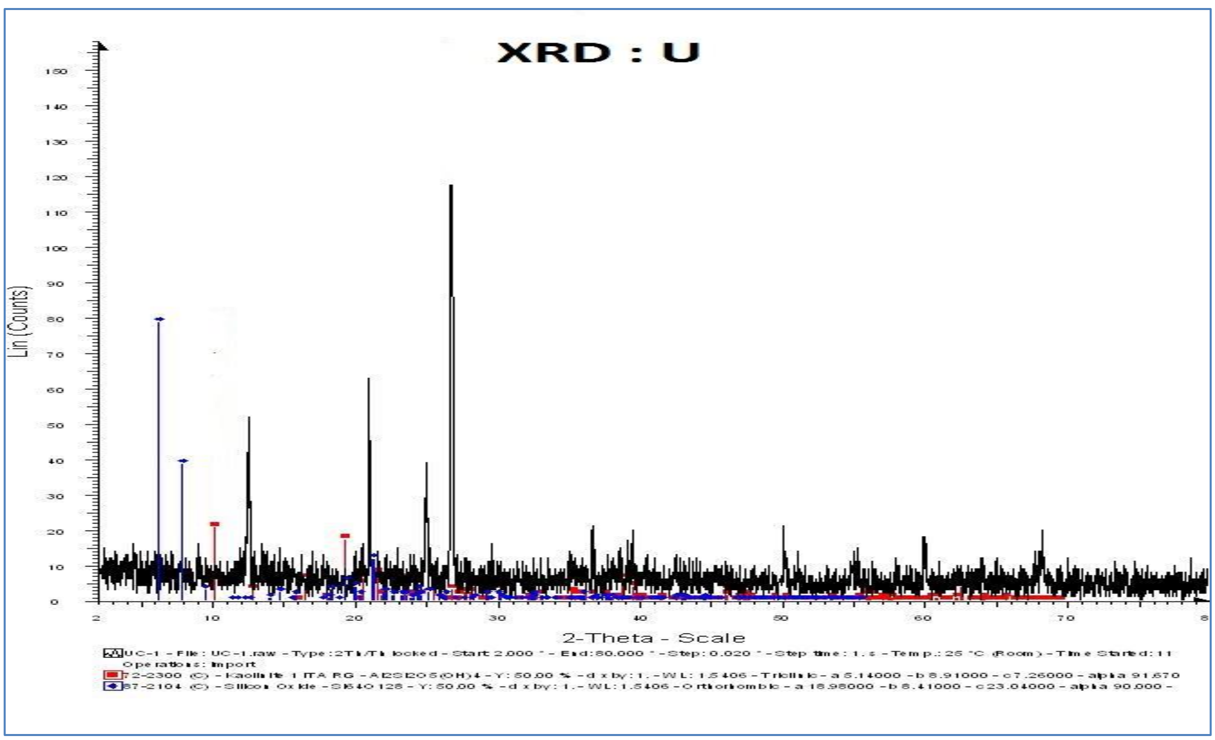

Figure 18: XRD results for sample U

4.7 Brightness, Whiteness and Yellowness Test

The brightness, whiteness and yellowness analysis for kaolin is an important test to study the quality of kaolin deposits in Simpang Pulai area. This test of brightness, whiteness and yellowness was conducted using raw kaolin samples which are not fired. Generally, the higher percentage of brightness and whiteness, and lower percentage of yellowness indicate a high grade or quality of kaolin.

Based from the results shown in the table below, all three samples of kaolin in Simpang Pulai possessed an excellent brightness percentage which is higher than 80%. Sample T-1 has brightness of 84.4%, T-2's brightness is 84.1%, and sample U's brightness is 83%. Sample T-2 has highest whiteness percentage which is 81.1% and lowest yellowness percentage, 2.39%. However, sample U which is undeveloped kaolin was found to have lowest brightness and whiteness (76.9%), and highest yellowness percentage (3.77%).

All in all, these sample show that the kaolin in Simpang Pulai is of good quality and can meet requirements for industrial uses such as in tiles manufacturing and other ceramic applications. Also, the undeveloped kaolin is considered good quality in terms of brightness, whiteness and yellowness and therefore can be a good potential kaolin resource in Simpang Pulai. This average brightness of kaolin in Simpang Pulai is considered higher than the average brightness of kaolin in Bidor area, may indicate its higher quality. This high brightness of the kaolin may be caused from the low content of iron oxide and titanium oxides, or impurities. The brightness can be further improved by using beneficiate method which is chemical bleaching by sodium dithionite.

Table 3: Brightness, whiteness and yellowness test results

Sample	Brightness (%)	Whiteness (%)	Yellowness (%)
T-1	84.4	80.8	2.41
T-2	84.1	81.1	2.39
U	83.0	76.9	3.77

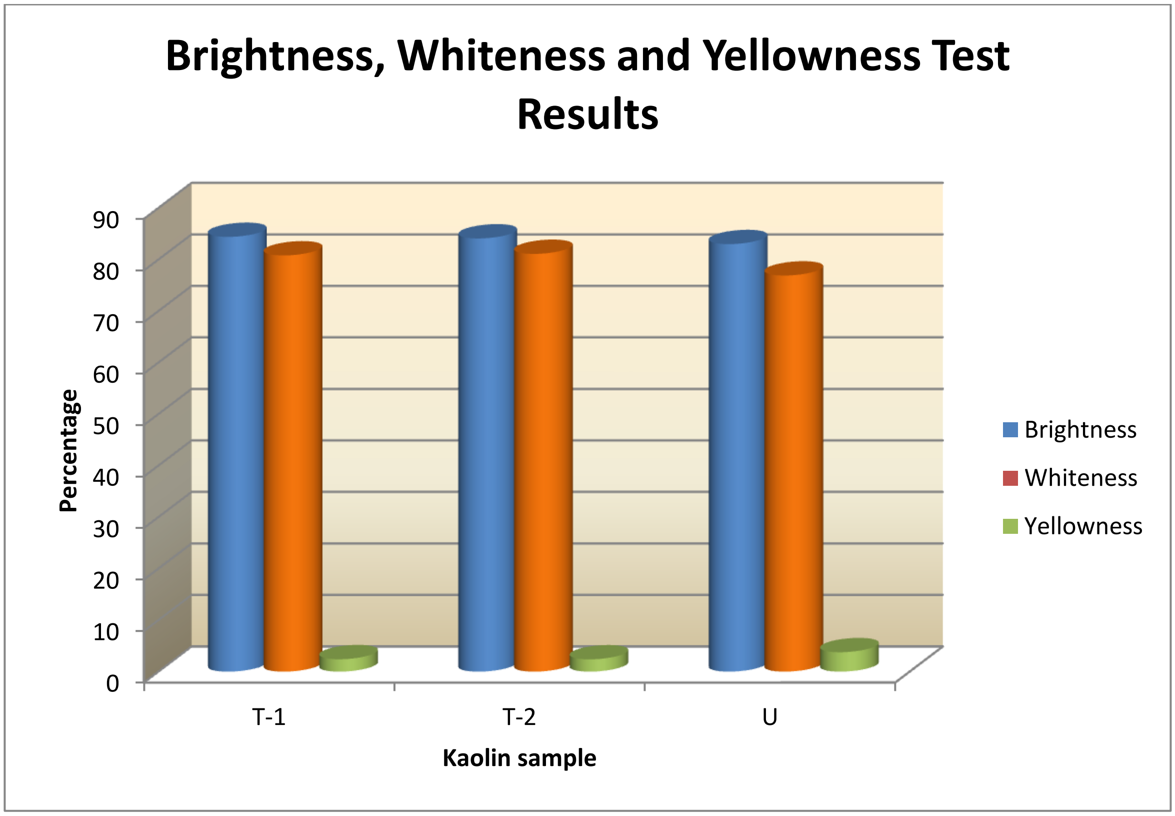

Figure 19: Brightness, whiteness and yellowness test results in chart

4.8 Particle Size Distribution

The kaolin quality can also be determined by particle size distribution analysis. Basically, the finer the grain size of the kaolin deposit the better the quality of the kaolin. The particle size distribution analysis was done using x-ray sedigraph machine and it is a very important analysis in kaolin quality test.

The particle size of kaolin was distributed into categories which are; more than 45µm, 30-45µm, 20-30µm, 5-10µm, 2-5µm, and lower than 2µm. The result for kaolin samples from mining pit, T-1 and T2, shows almost 100% of the particles have size lower than 30µm, specifically 97%. 70% of particles are under 10µm for T-1 sample while 65% of particles are under 10µm for T-2 sample. Approximately 23% of particles for sample T-1 and 21% of particles for sample T-2 have size lower than 2µm. Based on the results, it can be said that the kaolin deposits at the eastern side of the quarry have finer particle size compared to the western side of the quarry.

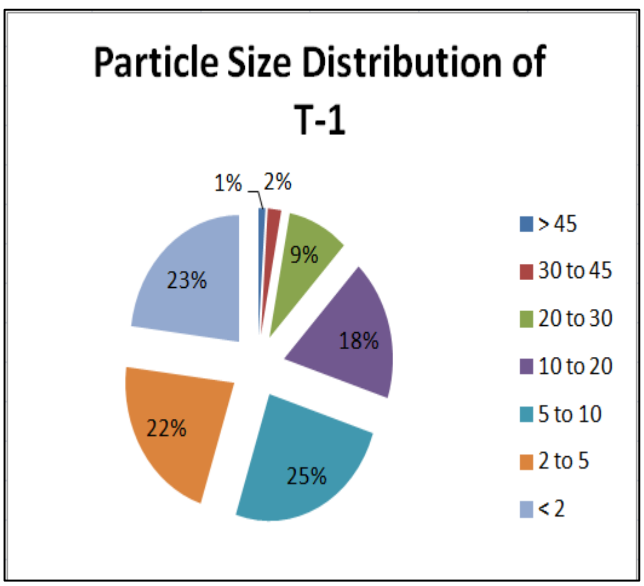

Figure 20: Particle size distribution test for sample T-1

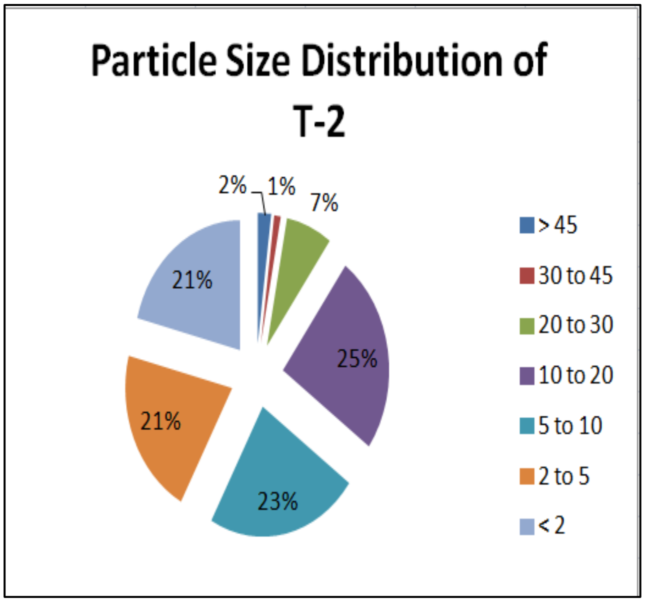

Figure 21: Particle size distribution test for sample T-2

Meanwhile, the undeveloped kaolin deposits represented by the sample U have considerably coarser particle size compared to samples from the quarry. Based on the result, 85% of the particles have size lower than 30µm. 51% of particles are under 10µm and about 15% of particles have size lower than 2µm.

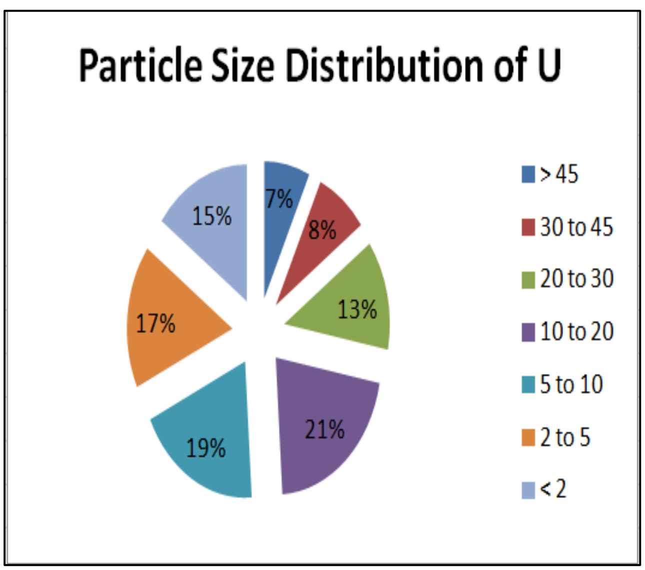

Figure 22: Particle size distribution test for sample U

Based on the results, the particle size for kaolin in Simpang Pulai area is considered of moderate to high quality due to its fine particle size. The kaolin sample taken at the eastern part of the quarry has the finest particle size while the undeveloped kaolin deposit has the least fine particle size. Moreover, several beneficiate methods such as mechanical grinding and hydrocyclone glass methods can be used in the future to improve or enhance the quality of the raw kaolin deposits in Simpang Pulai area.

4.9 LOI Test

LOI refers to Loss on Ignition test which is an analysis to determine the firing shrinkage of a material. It basically measures the mass loss of a combustion residue when it is heated to high temperature. This test is one of the methods of industrial characterization of the kaolin for ceramic industry and other uses. The LOI percentage value obtained from the test for all three samples are 6.53% for T-1, 6.52% for T-2 and 6.73% for U. This shows that the percentage of mass loss due to heating at high temperature for kaolin in Simpang Pulai is around 6%.

Table 4: LOI test results

Sample	LOI (%)
T-1	6.53
T-2	6.52
U	6.73

The low percentage of LOI for all the samples is showing that the kaolin has low firing shrinkage. This therefore indicates its thermal stability and it is of good quality. The max LOI percentage accepted for kaolin to be used in ceramic industry is 9.08% based on Prasad et al. (1991). Hence, the value of LOI shows that kaolin in Simpang Pulai can be used for ceramic industry applications.

4.10 Uses of the Kaolin in the Industry

The kaolin in Simpang Pulai area was found to have fine particle size and high percentage of brightness and whiteness. Thus, the kaolin has considerably good quality and technical properties in terms of physical and chemical. This kaolin may fulfill some industrial applications requirements and specification. The classifications of kaolin product by Associated Kaolin Industry Berhad (AKI) and British Geology Survey were combined and shown in the table below.

Table 5: classification of kaolin by British Geological Survey and Associated Kaolin Industry Berhad

Industrial Application	Brightness	Particle Size
Fertilizer	-	5% of 2µm
Ceramic	-	15% of 2µm
Filling	-	25% of 2µm
Paint Industry	79%	35% of 2µm
Paper & Rubber Industry	80%	45% of 2µm
Standard porcelain	-	97% under 10µm 65% of 2µm
Coating	-	97% under 10µm 79% of 2µm
Tiles	80%	A fraction is less than 63µm
Ceramic (higher grade)	91.87%	Less than 63µm

It is estimated that the undeveloped kaolin deposits, U, have reserves about 5000m^3. Based on the classifications shown, the kaolin in Simpang Pulai area, both developed and undeveloped kaolin, can be used for several applications such as ceramic industry, tiles manufacturing and fertilizer industry. Moreover, based on the appendix, the kaolin meets the requirements for the usage of filler clay, coating clay, paint and paper industry, only if the particle size is improved by beneficiate methods such as mechanical grinding and hydrocyclone glass.

Chapter 5: Conclusion and Recommendation

5.1 Conclusion

In conclusion, the main aims and objectives of the project have been achieved. A geological map on the scale of 1:50000 produced to display the general geology of the Simpang Pulai area. Geologically, this area consists of metasedimentary rock, limestone at west, granitic rock, granite which occupies central to eastern part of the area, and Schist which occupies the zone between Kinta Limestone and Slim Granite. Kaolin Occurrence was identified at northwest part of Simpang Pulai, specifically at Bukit Lampas slope. The kaolin in Simpang Pulai area is a product of both primary (in-situ) and hydrothermal weathering of minerals in granite batholiths such as feldspar, aplite and pegmatite. The occurrence of quartz-feldspar vein and nearby hot water spring which is Lubuk Timah indicates the hydrothermal fluid inlux system in the Simpang Pulai area. Based on the laboratory analysis and thin section analysis, the physical and chemical properties of different kaolin samples in the Simpang Pulai area can be analysed. Kaolinite is the dominant mineral in the kaolin, with quartz and feldspar are abundant. The kaolin in Simpang Pulai has good quality based on its fine particle size and high percentage of brightness and whiteness, and low impurities and LOI percentage. It can be used in several industry applications especially ceramic industry, tiles manufacturing and maybe fertilizer and filling.

5.2 Recommendation

In this project, several recommendations can be implemented. The kaolin samples can also be taken from other area such as Tapah and Bidor in order to get a correlation between the kaolin deposits in different areas. Hence, kaolin deposits in Simpang Pulai can be compared with the kaolin in Tapah and Bidor. The map will be corrected should the latest study shows different results than the expected map in the future. Also, a study on corundum mineral can also be done as the kaolin deposits in Simpang Pulai is believed to contain corundum. Moreover, a seismic acquisition study can also be conducted so that the subsurface image of Simpang Pulai area can be obtained.

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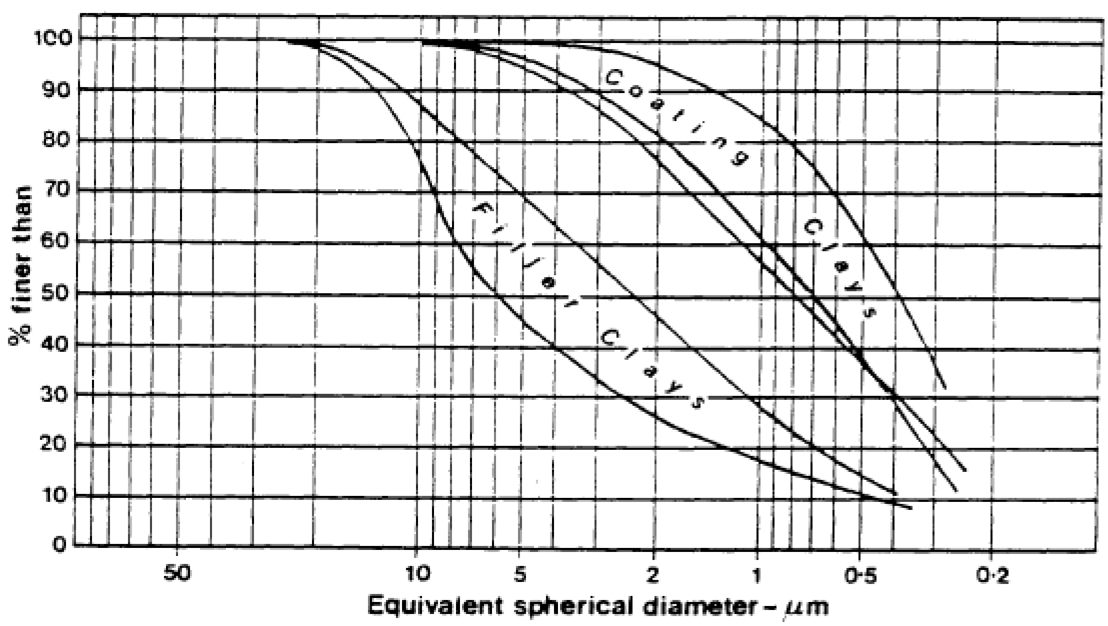
Appendix

	Filler clays	Coating clays
Raw ISO* brightness %	76 - 82	81.5 - 90.5
Yellowness%	5.7 - 8	4 - 6.5
% <2 μm	25 - 60	75 - 95
% >10 μm	6 - 25	0 - 6
% >53 μm	0.05 max	0.02 max
Viscosity concentration (% solids at 5 poise at 22°C)	61.2 - 71.5	64.2 - 74.5

* International Standards Organisation (ISO)

1: Typical properties of paper filler and coating kaolins by Highley, 1984



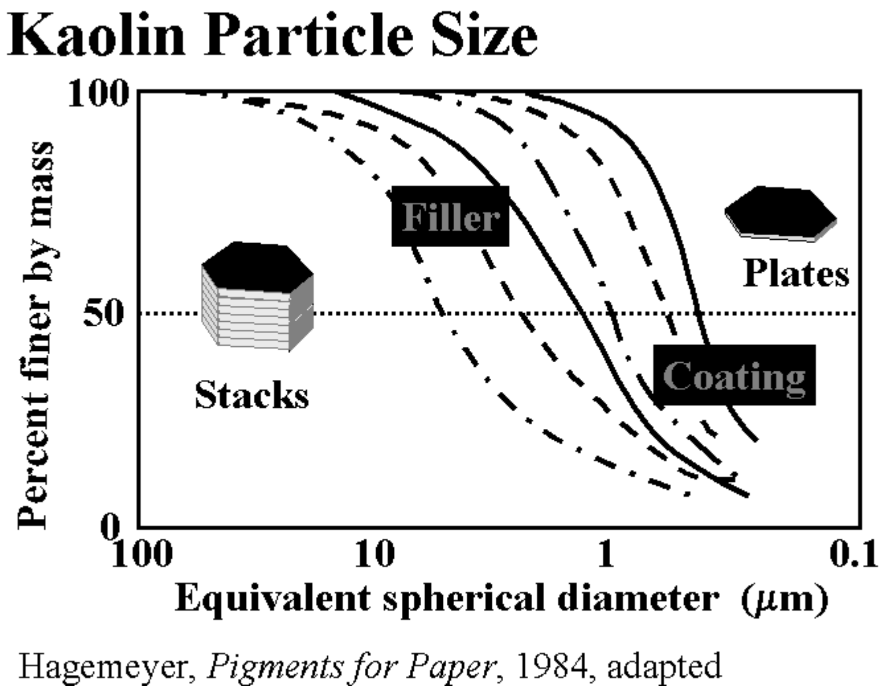
2: Particle size distribution of typical coating and filler grade kaolin by Highley, 1984

	(a)	(b)	(c)
SiO_2	47	48	48
Al_2O_3	38	37	37
Fe_2O_3	0.39	0.70	1.00
TiO_2	0.03	0.02	0.05
CaO	0.10	0.06	0.07
MgO	0.22	0.30	0.30
Na_2O	0.15	0.10	0.10
K_2O	0.80	1.85	2.00
LOI	13.0	12.2	12.1
% kaolinite	93	81	83
% micaceous material	4	15	13
% feldspar	1	1	2
% other minerals	2	3	2
%<2μm	85	57	40
%>10μm	1	10	20
Modulus of rupture (Kgf/cm^2)[1]	55.0	25.7	11.0
Casting conc. (weight % solids)	58.0	62.5	64.5
Deflocculant (5 poise [0.5 Pa.s])[2]	1.5	0.65	0.55
Casting rate (mm^2/min)	0.35	0.80	1.5
% Brightness (1180°C)[3]	95	86	82
% Shrinkage (1180°C)	10	9	7.5

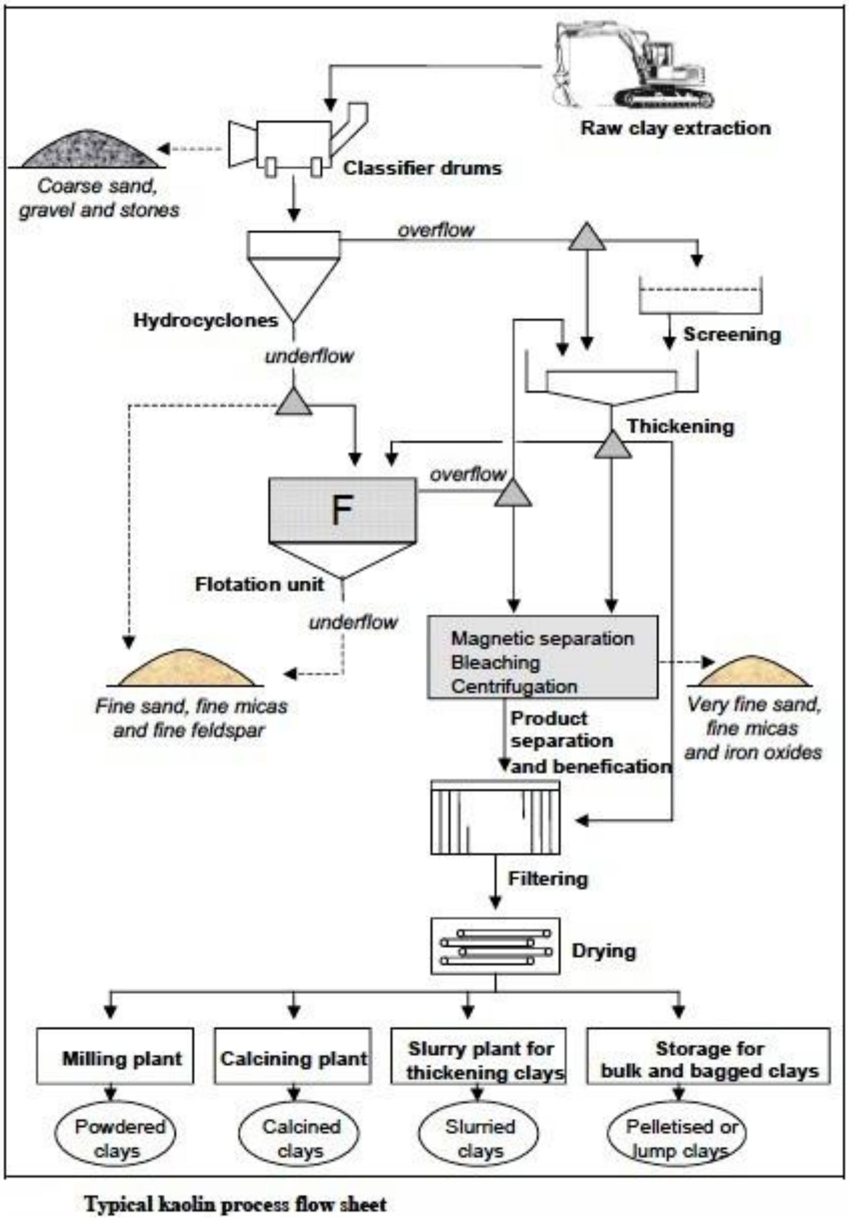
(a) ECC Super Standard Porcelain; high quality tableware, porcelain and bone china.
(b) ECC Grolleg; Earthenware, tableware.
(c) ECC Remblend; Sanitaryware.

1: Dried at 110°C.
2: Amount of P84 sodium silicate required for 5 poise slips.
3: At 457 nm wavelength.

3: Composition and properties of ceramic grade kaolin from English China Clay Technical Literature



4: Kaolin classification based on particle size



5: Typical beneficiate processes of Kaolin